

ASSIGNMENT OF LECTURER TO COURSES BASED ON OPTIMAL COMPETENCY SCORES USING MODIFIED HUNGARIAN METHOD (MHM) AND OPTIMIZATION MODEL

(Penetapan Pensyarah kepada Kursus Berdasarkan Markah Kompetensi Optimum Menggunakan Kaedah Hungarian yang Diubahsuai (MHM) dan Model Pengoptimuman)

NUR SYAHIRAH IBRAHIM, ADIBAH SHUIB* & ZATI AQMAR ZAHARUDIN

ABSTRACT

Effective assignment of lecturers to courses is a critical task in Higher Education Institutions in ensuring optimal utilization of faculty expertise and resources. Past related studies mostly used the Hungarian assignment method while the use of Modified Hungarian Method (MHM) optimization model is still lacking. Furthermore, competency-based lecturers to courses assignment involving knowledge, skills and teaching motivation has never been implemented. This paper presents a mathematical programming approach through an enhanced formulation of the MHM model. The competency-based MHM (C-MHM) model considers the competency scores of lecturers for courses involved in which the model's objective function is to maximize the total competency scores obtained from the lecturer-to-course assignments. Data on competency scores of lecturers across all undergraduate courses were collected from Mathematics lecturers in UiTM Shah Alam through online survey. The C-MHM model with competency scores as input data was solved using MATLAB intlinprog to generate an optimal teaching assignment plan where lecturers have been assigned to teach a maximum of three courses. The optimal solutions of this competency-based C-MHM model indicates which courses are the best to assigned to a particular lecturer based on competency levels measured using three factors namely knowledge, skills and teaching motivation. Analysis of these results reflect the proficiency and suitability of each lecturer for the assigned courses. The key contribution of the approach in our study is the adaptation of the MHM optimization model to incorporate the lecturers' competency levels and other multidimensional inputs efficiently. The model aims to improve teaching quality, reduce mismatches, and enhance overall academic performance.

Keywords: lecturers-to-courses assignment; competency; Modified Hungarian Method; mathematical programming model; higher education institutions

ABSTRAK

Penetapan pensyarah kepada kursus secara berkesan adalah tugas yang kritikal di Institusi Pengajian Tinggi dalam memastikan penggunaan kepakaran dan sumber fakulti yang optimum. Kajian yang berkaitan sebelum ini kebanyakannya menggunakan kaedah penetapan Hungarian (HM) manakala penggunaan model pengoptimuman kaedah Hungarian yang diubahsuai (MHM) masih kurang. Tambahan pula, penetapan pensyarah kepada kursus berasaskan kompetensi yang melibatkan pengetahuan, kemahiran dan motivasi pengajaran belum pernah dilaksanakan. Kertas kerja ini membentangkan pendekatan pengaturcaraan matematik melalui formulasi model MHM yang dipertingkatkan. Model MHM berasaskan kompetensi (C-MHM) mengambilkira skor kompetensi pensyarah bagi kursus-kursus yang terlibat yang fungsi objektif model adalah untuk memaksimumkan jumlah skor kompetensi yang diperolehi penetapan pensyarah-ke-kursus. Data skor kompetensi pensyarah merentasi semua kursus sarjana muda telah dikumpul daripada pensyarah Matematik di UiTM Shah Alam melalui kaji selidik atas talian. Model C-MHM dengan skor kompetensi sebagai data input telah diselesaikan menggunakan MATLAB intlinprog untuk menjana pelan penetapan pengajaran yang optimum.

di mana pensyarah diberikan maksimum sebanyak tiga kursus. Penyelesaian optimum model C-MHM berasaskan kompetensi ini menunjukkan kursus-kursus mana yang terbaik untuk diberikan kepada pensyarah tertentu berdasarkan tahap kompetensi yang diukur menggunakan tiga faktor iaitu pengetahuan, kemahiran dan motivasi pengajaran. Analisis keputusan ini mencerminkan kecekapan dan kesesuaian setiap pensyarah untuk kursus-kursus yang ditetapkan. Sumbangan utama pendekatan dalam kajian kami ialah pengadaptasian model pengoptimuman MHM untuk menggabungkan tahap kompetensi para pensyarah dan input pelbagai dimensi dengan cekap. Model ini bertujuan untuk meningkatkan kualiti pengajaran, mengurangkan ketidaksepadanan, dan meningkatkan prestasi akademik secara keseluruhan.

Kata kunci: penetapan pensyarah-ke-kursus; kecekapan; kaedah Hungarian yang diubahsuai; model pengaturcaraan matematik; institusi pengajian tinggi

1. Introduction

A lecturer plays a pivotal role in shaping the academic experience for students, bringing a rich blend of expertise, passion, and dedication to the table. With a background deeply rooted such as in foundation and pure Mathematics, the lecturers in Mathematics department not only imparts theoretical knowledge but also provides practical insights and real-world applications that enrich the students' learning journey. These lecturers' teaching philosophy emphasizes the approaches such as critical thinking, problem-solving, or hands-on learning, fostering a deeper understanding of complex concepts and encouraging students to explore beyond the classroom. Competence, as defined by Collin's dictionary, is "the quality of being competent; adequacy; possession of required skill, knowledge, qualification, or capacity" (Collins English Dictionary 2024). According to Hölzer *et al.* (2017), teaching competency encompasses not only subject knowledge, but also a learner-centered approach, social and communication skills, role-modelling professional behaviour, reflective practise, and systems-related practise. Hungarian method (HM) is one of the methods that have been implemented for lecturer-to-course assignment. HM is a combinatorial optimization algorithm used to solve the assignment problem, which involves assigning a set of resources to a set of tasks while optimizing a certain objective, such as minimizing cost or maximizing efficiency. HM obtains the optimal solution by finding the optimum value for each row or column by first subtracting the minimum value in each row and column (row and column reductions). It becomes a fundamental tool in various fields such as operations research, computer science, and economics. The modified HM (MHM) builds upon the original HM algorithm by introducing enhancements or adjustments to address specific constraints or improve performance in certain scenarios.

However, past related studies mostly used the HM while the use of MHM for lecturers to courses assignment is still lacking. We have been the first to propose the MHM optimization model for lecturer-to-course assignment (Ibrahim *et al.* 2024). HM in general deals with balanced assignment problems whereas MHM is capable of handling the unbalanced assignment problems. Often, when assigning lecturers to courses, the number of lecturers and courses are not the same, thus, we have unbalanced assignment problem. In addition, past studies on lecturers to courses assignment problems mostly consider lecturers' preferences as the objective function of the optimization model. Thus far, mathematical programming model for such problems which consider lecturers' competency level as the objective function has not been explored by past studies. Furthermore, different competencies of lecturers for courses across areas of Mathematics can occur.

This paper focuses presenting the adaptation and modification of the MHM model in solving the lecturer-course assignment problem in which the unbalanced assignment problem that can

be due to the number of lecturers and courses are not the same is being addressed by the use of MHM. Meanwhile, the model's objective function is to maximize the total competency scores. By incorporating competency scores in the objective function, the MHM model enables the assignment of each lecturer to courses to be based on his/her perceived level of competency for the courses involved. Achieving optimal assignment of lecturers to courses based on their competency levels can be crucial in ensuring high quality teaching and learning in Higher Education Institutions. The competency-based MHM (C-MHM) model and approach used in our study acknowledges that lecturers possess different competencies for different courses based on their diverse expertise and strengths, and leveraging on these competencies can lead to more effective teaching and learning experiences. Insights gathered through the survey done in our study which concerns with lecturers' competency levels as well as their preferences toward courses ensures that the university can arrive at data-driven decisions when assigning lecturers to courses. Advanced optimization model to match lecturers with courses based on their competency scores can be significance to the university in achieving excellence and efficiency in T&L for academic excellence and overall quality achievement.

2. Literature Review

The assignment of lecturers to courses based on competency scores has become a crucial aspect in education management, to optimize resource allocation and enhance teaching quality. This task falls under the domain of assignment problems in optimization theory, which involves the allocation of resources to tasks in a way that minimizes or maximizes certain objectives, such as cost, time, or distance. According to Latip *et al.* (2020), lecturer competency is one of the primary service quality experiences by students. Meanwhile, lecturers' competency is the most important factor that influences students' achievement and satisfaction. In recent years, researchers explored various optimization models and algorithms to address this complex assignment problem. One prominent approach that has gained attention is the MHM, which extends the classical Hungarian method to incorporate competency scores and other relevant factors into the assignment process. The Hungarian method, originally developed by Kuhn and Munkres in the 1950s, provides an efficient algorithm for solving assignment problems based on a cost matrix. It aims to find an optimal assignment that minimizes the total cost or maximizes the total benefit, considering the constraints of assigning tasks to resources (Kuhn 1955). While the traditional HM has been widely used in various domains, its application to the assignment of lecturers to courses requires enhancements to handle certain unbalanced assignment situations. Based on Rabbani *et al.* (2019), the MHM differs from HM in terms of MHM can be used for unbalanced assignment problems. Nevertheless, past studies that implemented MHM in assignment of lecturer to courses are still lacking and competency-based MHM model for lecturer to courses assignment can be considered novel.

There have been few previous studies concerning the assignments of academic staff or lecturers to specific courses (subjects). Most of these studies use HM to solve balanced assignment problem involving equal number of rows and number of columns for the assignment table. Mallick *et al.* (2021) present a case study using the HM that explores the Course and Lecturer Assignment Problem Solvation (CLAPS) process used by a tertiary institution's course coordinator. The authors assign a number of courses to an equal number of faculties to manage the listed courses in the various lecturers-to-course assignments at the educational institution in which they achieved the most effective and least expensive allocation and assignment for the problem. Meanwhile, Solaja *et al.* (2020) used the HM to solve the assignment problem in a Nigerian education institution, and the HM assignment model in course allocation helped the institution attained a 13.20% increase in lecturers' effectiveness in analyzing each topic for

business decisions. Kabiru *et al.* (2017) used the HM optimization model and LINGO software in an optimal assignment schedule of staff-to-subject allocation where the model produces optimal solution for assigning the staff to the courses. The HM model's objective function is to maximize the total effectiveness of the teaching-learning process. Wattanasiripong and Sangwaranatee (2021) used HM to minimize lecturer preparation time and to match lecturers to courses based on individual expertise. The results of the study show that this method potentially improves teaching quality as the lecturer-to-course assignment is based on expertise. Meanwhile, Ahmed *et al.* (2022) solved the teacher's assignment problem, which involves assigning teachers to classes effectively and with minimum cost. HM was implemented using computer software like Excel QM that facilitates decision-making for such assignment tasks. The authors found that manual computations using the HM yielded the same results as using QM software. Udok and Victor-Edema (2023) focus on assigning Mathematics/Statistics Department lecturers to postgraduate courses by implementing HM using manual computation in which HM is effective in producing the optimal solution.

Based on the past studies, allocation and assignment of lecturers to courses for unbalanced assignment problem, that is for the number of lecturers and courses is not the same (number of rows $\neq$ number of columns in assignment table), is seldom considered. Many studies made the assumption that these numbers of lecturers and courses are the same. However, often these numbers are not the same. As mentioned earlier, MHM is recommended in handling unbalanced assignment problem. Among the latest studies which used is the study by Elsisy *et al.* (2020), who applied the MHM in the reuse of valuable buildings in Egypt by making a comparison between four valuable buildings that are reused in several activities. The significance in building research is to reach the best benefit of building reuse, which should be matching with the basic purpose of the building and to preserve the value of the building. Hence, this method can provide fewer efforts and time to reach optimality, compared to the existing methods. Meanwhile, MHM has also been used by Zhang *et al.* (2021) to assign pursuers and control methods in multi agent pursuit evasion under uncertainty. The results showed that this method outperformed a nearest-neighbour based assignment algorithm. Wei *et al.* (2022) applied MHM to reduce federated learning training delays across wireless channels, which were limited by overall training performance as well as each client's differing privacy requirements.

In addition, in the study by Liu *et al.* (2021), MHM was employed to assign subchannels to IoT devices, which effectively mitigates interference where the total transmission power decreases significantly after applying the proposed algorithms. Ge *et al.* (2020) used MHM for IoT in terms of Parked Vehicle Edge Computing (PVEC). It was proven that MHM efficiently dealt with the tough task of selecting Parked Vehicles (PVs) with various energy and services and the simulation results show that the total transmission power decreases significantly after applying MHM algorithms. Lastly, Mukherjee and De (2023) focus on device to device (D2D) multicasting in 5G networks, addressing interference in underlay D2D mode for quality of service (QoS) by using the MHM for resource block (RB) allocation in cluster-based D2D communications to develop an intelligent clustering algorithm for maximizing network sum-rate. Based on the described past studies which used MHM, the MHM can be implemented in various applications with significant benefits in terms of improvement of the current systems. The characteristics of these past related studies related to MHM are summarized in Table 1.

Table 1: Past studies related to MHM

Authors	Area of Application	Solution Methods	Software/System Used	Multi-Objective	Optimization Model for Assignment Problem
Elsisy <i>et al.</i> (2020)	Fuzzy Assignment problem	MHM; α -Cut Method	Manual Calculation (not using any software)	Multi-objective (get the optimum solution of the fuzzy AP and assignment cost in the fuzzy)	Achieve minimum assignment cost to get the best benefit of building reuse
Ge <i>et al.</i> (2020)	Internet-of Things (IoT)	MHM; Lyapuunov optimization	PVEC system	Multi-objective (two-stage service migration algorithm for PVEC networks and the serving PV selection in parking lots)	Assign subchannels to the Internet-of-Things (IoT) devices and selecting Parked Vehicle Edge Computing (PVEC) with various energy and services
Liu <i>et al.</i> (2021)		MHM; improved K-means method; alternating iterative method; golden section search method	does not stated by authors	Multi-objective (minimize the total transmission power between different IoT devices and the limited number of channels of a UAV)	MHM based dynamic many-many matchings (HD4M) algorithm
Zhang <i>et al.</i> (2021)	Assignment of Redundant pursuers	MHM; Markov localization	CVX: MATLAB	Multi-objective (minimize total capture time of the uncertainties and minimize maximum capture time)	Assign pursuers and control methods in multi-agent pursuit-evasion under uncertainty
Wei <i>et al.</i> (2022)	Federated learning training	MHM; Greedy Matching with a Better Alternative (GMBA)	CIFAR-10; FashionMNIST	Multi-objective (minimize FL training delay over wireless channels and for each client's differential privacy (DP) requirement)	Reduce federated learning training delays across wireless channels, which were limited by overall training performance and each client's differing privacy requirements
Mukherjee and De (2023)	Device to device (D2D) Multicasting	MHM	network simulator	Maximize the obtained sum rate of the network	Frame a suitable D2D multicasting in underlay cellular network with appropriate resource allocation

As shown in Table 1, past studies have applied MHM in various areas of applications, but none concerned with lecturers-to-courses assignment problem and, in particular, the use of mathematical programming model for the implementation of MHM in solving the problem. We introduced the use of MHM in solving lecturers-to-courses assignment problem in our study which deals with assigning lecturers to courses based on optimal solution found using MHM optimization models. We proposed five variants of MHM models which objective function is to maximize the lecturers' preferences score or to maximizes the lecturers' competency levels, and also considering multiple objectives involving both, which are solved using goal programming methods (Ibrahim *et al.* 2024). In this paper, we present the competency-based MHM (C-MHM) model where three elements of competency, namely, knowledge, skills and teaching motivation have been considered. C-MHM model targets to address the unbalanced problem of lecturers to courses assignment as well as considering competency levels as the objective function of the model. The proposed competency-based C-MHM model aims to determine the optimal lecturer-to-course assignments by optimizing the competency scores evaluated based on knowledge, skills, and teaching motivation.

3. Methodology

This study comprises of four phases, which are Data Collection and Analysis, Enhanced Formulation of MHM, Computational Experiments, and Analysis of Results, as shown in Figure 1. For the first phase which is Data Collection and Analysis, data were collected in the semester of March to August, 2023 via online survey distributed to 45 lecturers in Mathematics department of the College of Computing, Informatics and Mathematics of Universiti Teknologi MARA (UiTM), Shah Alam. This study involves 35 undergraduate Mathematics courses. The survey aimed at determining lecturers' competency levels. Respondents rated a series of statements on a Likert scale to provide numeric data for these subjective traits. Based on South *et al.* (2022), Likert scale enables researchers to gather numeric data on subjective traits, allowing for summary and visualization like other quantitative data. The Likert scale is one of the most commonly used and essential psychometric tools in educational and social science research (Joshi *et al.* 2015). The respondents (lecturers) have to rate the given statements concerning their competency levels (Knowledge, Skills and Teaching Motivation) on each course according to their perceived level of competency represented by the given Likert scale. The following are the respective Likert scales for each of the three elements of competency shown in Table 2, Table 3 and Table 4.

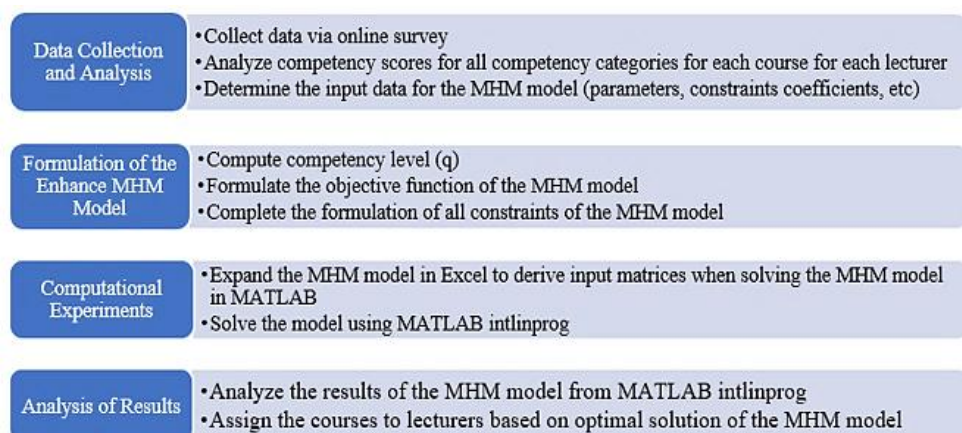


Figure 1: Four phases of this study

Table 2: Likert scale for lecturer's knowledge competency of a course

Scale	Description	Justification
1	Beginner	Has a basic level of knowledge.
2	Competent	A person who has the knowledge, advanced than a beginner but not yet proficient.
3	Proficient	A person who is highly competent but not yet an expert.
4	Expert	Subject matter expert recognized by virtue of credentials, training, education, profession, publications, or experiences.

Table 3: Likert scale for lecturer's skills competency of a course

Scale	Description	Justification
1	Basic	Has a basic level of skills that is expected to have some knowledge of the specified activity and its terminology and concepts.
2	Capable	Can carry out standard relevant tasks confidently and consistently without supervision.
3	Accomplished	Can carry out complex, specialist, or non-standard tasks confidently and consistently.
4	Authoritative	Widely recognized as an authority, external peers and by others in the organization for the knowledge and experience that have been demonstrated.

Table 4: Likert scale for lecturer's teaching motivation competency of a course

Scale	Description	Justification
1	Basic	Has a basic level of skills that is expected to have some knowledge of the specified activity and its terminology and concepts.
2	Capable	Can carry out standard relevant tasks confidently and consistently without supervision.
3	Accomplished	Can carry out complex, specialist, or non-standard tasks confidently and consistently.
4	Authoritative	Widely recognized as an authority, external peers and by others in the organization for the knowledge and experience that have been demonstrated.

Data analysis was then carried out to obtain the average competency score for each course for each individual lecturer. This is done by taking the sum of scores for all elements of competency for each course and divided it by 12, which is the maximum values for the three elements to get a value between 0 to 1. This average competency score is to be assigned a value q . If $0 < \text{average} \leq 0.25$, then $q = 1$. If $0.25 < \text{average} \leq 0.50$, then $q = 2$ whereas if $0.50 < \text{average} \leq 0.75$, $q = 3$. Otherwise, if $0.75 < \text{average} \leq 1.00$, $q = 4$. For example, Lecturer A1 have scores for knowledge (2), skills (3) and teaching motivation (3), then the average competency score $= (2 + 3 + 3)/12 = 0.67$. The final competency scores for Lecturer A1 is $q = 3$ because the average is between $0.50 < \text{average} \leq 0.75$.

The next phase which is Enhanced Formulation of the MHM Optimization Model, the expansion of MHM optimization model was done in Excel using the data gathered and competency score (q) as coefficients of the objective function of the model. The input matrices found from expansion in Excel were then used to solve the model using MATLAB intlinprog. The objective function of the enhanced MHM model is to maximize the competency score of lecturers on courses. The formulation of the enhanced MHM model is as the following.

3.1 The MHM model for maximizing competency scores (C-MHM model)

Our study has developed five variants of the enhanced MHM model for lecturer-to-course assignment problem in which one of them is the MHM model for maximizing competency scores (C-MHM model). The C-MHM model formulation is as follows:

C-MHM Model Formulation

Notation – Sets, Indices, Parameters, and Input Variables:

- m : number of lecturers ($m = 39$)
- n : number of courses ($n = 35$)
- i : index for lecturers
- j : index for courses
- c_{ij} : lecturer i competency to get course j
- $x_{ij} = \begin{cases} 1, & \text{lecturer } i \text{ is assigned course } j \\ 0, & \text{otherwise} \end{cases}$

$$\text{Maximize } Z_1 = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij} \quad (1)$$

subject to

$$\sum_{i=1}^m x_{ij} \geq 1 \quad , j = 1, 2, 3 \dots n \quad (2)$$

$$\sum_{j=1}^n x_{ij} \geq 1 \quad , i = 1, 2, 3 \dots m \quad (3)$$

$$\sum_{i=1}^m x_{ij} \leq 3 \quad , j = 1, 2, 3 \dots n \quad (4)$$

$$\sum_{j=1}^n x_{ij} \leq 3 \quad , i = 1, 2, 3 \dots m \quad (5)$$

$$x_{ij} = \{0, 1\} \quad , i = 1, 2, 3 \dots m; j = 1, 2, 3 \dots n \quad (6)$$

The objective function is presented in Eq. (1) which is to maximize the competency score of lecturers for courses. Constraint (2) is to ensure that one lecturer should be assigned to at least one course. On the other hand, Constraint (3) guarantees that a course must be assigned to at least one lecturer. Constraint (4) restricts that one lecturer can only be assigned to at most three courses. Meanwhile, Constraint (5) dictates that one course can only be assigned to at most three lecturers. Finally, Constraint (6) present the restriction on value of decision variables in which the binary decision variables only take binary value of either 0 or 1.

Before solving the C-MHM model using MATLAB, model's expansion was carried out to determine vectors and matrices which are the parameters of the MATLAB intlinprog. These vectors include vectors of the objective function coefficients (**f**) and Right-Hand-Side (RHS) of inequality constraints (**b**). matrix denotes the technology matrix or coefficients of the inequality constraints (**A**). Input vectors and matrices of MATLAB intlinprog are as shown in Figure 2.

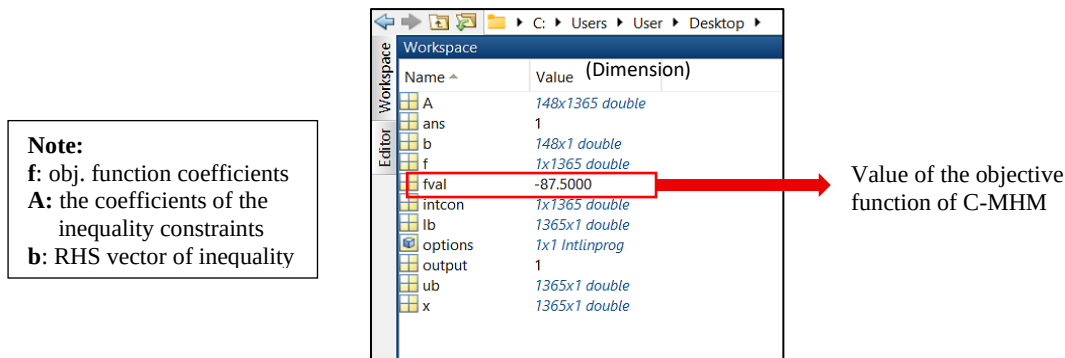


Figure 2: MATLAB workspace for C-MHM

The third phase is Computational Experiments where the expanded model was solved using MATLAB's intlinprog solver. The input matrices and vectors derived in Excel were provided as parameters for the solver, enabling precise computation of the optimization problem. The objective function of the enhanced MHM model aimed to maximize the competency scores of lecturers assigned to courses. Lastly, the last phase is the Analysis of Results which the results obtained from MATLAB were analyzed to assess the effectiveness of the enhanced MHM model in assigning lecturers to courses optimally. Figure 2 illustrates the input matrices and vectors used in the computational process, highlighting the reproducibility of the methodology.

4. Results and Discussion

A total of 39 out of 45 lecturers responded to the questionnaires. Figure 3 shows that there are six males (15%) lecturers and 33 females (85%) lecturers who completed the questionnaire. Table 5 presents the list of Mathematics courses offered by the Mathematics Department at UiTM Shah Alam. The MATLAB intlinprog generates optimal solutions which contain the objective function value (fval) and the values of the decision variables (x_{ij}) which has either a value '1' or '0'. Note that the objective function of C-MHM is to maximize the competency score of lecturers for courses. The fval value for the C-MHM model is as shown in Figure 2, which is -87.50. Note that MATLAB default is to minimize the objective function thus, the command is to minimize the negative of the objective function of C-MHM. Thus, the maximum competency score of lecturers to courses is 87.50. The values of '1's and '0's obtained from MATLAB intlinprog are transferred to Excel spreadsheet to better illustrates the assignment of each lecturer to courses. The results obtained based on maximization of total lecturers' competency score are as displayed in Table 6, where each lecturer is assigned one up to three courses while each course can only be taught by not more than three lecturers.

Based on Table 6, lecturers A7, A18, and A21 are assigned only one course each, while A11, A20, A23, A26, A32, and A35 are assigned two courses. The remaining lecturers, including A1, A2, A3, and so forth, have been assigned three courses each. The results reflect that courses have been assigned to suit the competency level (scores obtained based on Knowledge, Skills and Teaching Motivation). Besides that, it is also found that this optimal solution of lecturers to courses assignments also displays that these courses reflect the areas of expertise of the lecturers. Table 6 also summarizes the lecturer-to-course assignments of all the lecturers involved.

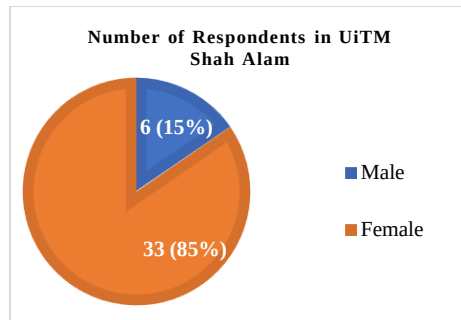


Figure 3: Respondents' gender

Table 5: List of Mathematics courses in UiTM Shah Alam

No.	First Year Courses	No.	Second Year Courses	No.	Third Year Courses
1	MAT402(Business Mathematics)	16	MAT512(Number Theory)	31	MAT612(Partial Differential Equations)
2	MAT406(Foundation Mathematics)	17	MAT522(Ordinary Differential Equations)	32	MAT631(Complex Analysis with Computational Applications)
3	MAT415(Discrete Mathematics)	18	MAT523(Linear Algebra II)	33	MAT 652(Algebraic Structures)
4	MAT417(Mathematics)	19	MAT525(Coding and Cryptography)	34	MAT633(Fuzzy Set Theory)
5	MAT421(Calculus I)	20	MAT530(Introduction to Mathematical Modelling)	35	MAT668(Graph Theory with Applications)
6	MAT422(Mathematical Logic and Proving Techniques)	21	MAT531(Advanced Mathematical Modelling)		
7	MAT423(Linear Algebra I)	22	MAT538(Applied Mathematics)		
8	MAT435(Calculus for Engineers)	23	MAT560(Vector Calculus)		
9	MAT438(Foundation of Applied Mathematics)	24	MAT565(Advanced Differential Equations)		
10	MAT441(Calculus II)	25	MAT570(Mathematics Economics)		
11	MAT455(Further Calculus for Engineers)	26	MAT571(Real Analysis)		
12	MAT472(Foundation of Mechanics)	27	MAT575(Introduction to Numerical Analysis)		
13	MAT480(Further Differential Equations)	28	MAT578(Mathematical Methods)		
14	MAT491(Calculus III)	29	MAT580(Further Differential Equations)		
15	MAT495(Partial Derivatives and Approximation Methods)	30	MAT583(Applied Numerical Methods)		

Table 6: The result from MATLAB for courses of each lecturer

Courses	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Lecturers	MAT 402	MAT406	MAT 415	MAT417	MAT421	MAT422	MAT423	MAT 435	MAT 438	MAT441	MAT 455	MAT 472	MAT 480	MAT491	MAT495	MAT512	MAT522	MAT523	MAT525	MAT530	MAT531	MAT538	MAT560	MAT 565	MAT570	MAT571	MAT 575	MAT 578	MAT 580	MAT 583	MAT 612	MAT 631	MAT 652	MAT633	MAT668
A1															1		1														1				
A2			1																	1															1
A3	1		1									1																							
A4		1																					1											1	
A5																											1	1							1
A6	1								1	1																									
A7																							1												
A8								1			1																								1
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A39					1						1				1																				

Table 7 shows the compilation of results shown in Table 6. Examples of the optimal assignments include for instance, Lecturers A7 and A18 are assigned only one course which is MAT560 (Vector Calculus) for A7 and MAT575 (Introduction to Numerical Analysis) for A18. Meanwhile, there are also lecturers who have been assigned with two courses. For example, Lecturer A20 is assigned two courses namely MAT421 (Calculus I) and MAT 652 (Algebraic Structures) while Lecturer A35 is assigned MAT525 (Coding and Cryptography) and MAT668 (Graph Theory with Applications). Lecturers can be assigned up to three courses. For instance, Lecturer A9 is assigned MAT512 (Number Theory), MAT 530 (Introduction to Mathematical Modelling) and MAT 531 (Advanced Mathematical Modelling) whereas Lecturer A14 is assigned MAT 423 (Linear Algebra I), MAT 472 (Foundation of Mechanics) and MAT 523 (Linear Algebra II).

Several lecturers are also assigned to teach courses at various levels of the undergraduate program, with lecturers like A1, A2, A4, A16, A24, A28, and A31 assigned to the first digit of the code (4, 5 and 6) where code represents the year course is offered which is first year, second year or third year of undergraduate program. This suggests extensive experience and competence among these lecturers. Conversely, lecturers such as A3, A6, A17, A22, A29, and A39 specialize in first-year courses, whereas A5, A19, A33, and A35 focus on second and third-year courses, demonstrating their adeptness in higher-level Mathematics. Overall, this structured assignment of courses to lecturers based on competency ensures better learning experience for students and supports faculty development, highlighting the importance of a strategic approach to lecturer-to-course assignments within the Mathematics department.

Table 7: Result of lecturer to course assignment based on competency scores

Lecturer	Courses			Lecturer	Courses		
A1	MAT495	MAT522	MAT 612	A21	MAT 583		
A2	MAT 415	MAT530	MAT668	A22	MAT441	MAT 472	MAT491
A3	MAT 402	MAT 415	MAT 472	A23	MAT422	MAT570	
A4	MAT406	MAT 565	MAT633	A24	MAT491	MAT522	MAT 631
A5	MAT 578	MAT 580	MAT633	A25	MAT 435	MAT441	MAT531
A6	MAT 402	MAT 438	MAT441	A26	MAT522	MAT538	
A7	MAT560			A27	MAT417	MAT570	MAT 583
A8	MAT 435	MAT 455	MAT633	A28	MAT 438	MAT525	MAT668
A9	MAT512	MAT530	MAT531	A29	MAT406	MAT421	MAT423
A10	MAT 438	MAT525	MAT538	A30	MAT 480	MAT495	MAT 612
A11	MAT406	MAT 631		A31	MAT422	MAT571	MAT 631
A12	MAT417	MAT 455	MAT 575	A32	MAT491	MAT570	
A13	MAT523	MAT538	MAT 575	A33	MAT512	MAT531	MAT 652
A14	MAT423	MAT 472	MAT523	A34	MAT530	MAT 565	MAT 580
A15	MAT 435	MAT523	MAT571	A35	MAT525	MAT668	
A16	MAT417	MAT560	MAT 612	A36	MAT 402	MAT 480	MAT 565
A17	MAT 415	MAT422	MAT423	A37	MAT 480	MAT 578	MAT 580
A18	MAT 575			A38	MAT560	MAT 578	MAT 583
A19	MAT512	MAT571	MAT 652	A39	MAT421	MAT 455	MAT495
A20	MAT421	MAT 652					

The analysis of the optimal solutions of the C-MHM model presented in Table 6 and Table 7 demonstrates the suitability and proficiency of lecturers to their assigned courses. The significant contribution of this study lies in integrating competency-based approach in lecturer-to-course assignment process and adapting the MHM algorithm to handle multidimensional inputs effectively. Additionally, this research is expected to provide insights concerning

lecturers' profiles and their perceived competency levels, offering new ideas for enhancing T&L quality and academic performance across all disciplines, not just Mathematics. By considering lecturer competencies in their assignment of courses to teach, the C-MHM model seeks to minimize mismatches in lecturer-to-course assignments and to improve lecturers' satisfaction.

5. Conclusion

In conclusion, the analysis of the assignment of lecturers to courses based on competency scores highlights the complexity and importance of optimizing this process in educational institutions. The findings emphasise the need for a systematic approach to ensure balanced workloads, effective course coverage, and alignment with lecturer expertise. The proposed enhanced MHM optimization model presents a promising solution to address these challenges in assigning lecturers to courses. In this paper, a variant of our formulated enhanced MHM models which is the C-MHM model which objective function is to maximize the total competency score of all lecturers has been presented. By leveraging the MHM model, future work can focus on refining the assignment process. This includes defining clear and measurable competency metrics for lecturers, implementing continuous evaluation mechanisms, and integrating dynamic updates based on evolving educational needs. The outcomes highlight not only improved lecturer-to-course assignments but also potential resource savings and increased satisfaction especially among lecturers. In conclusion, this study outlines the importance of competency-driven lecturer assignment and showcases the viability and benefits of the MHM model in optimizing such complex educational allocation tasks. Future research directions may explore additional variables, scalability, and real-world implementation strategies to further enhance the model's practical utility and impact in educational institutions.

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College of Computing, Informatics and Mathematics
University Teknologi Mara (UiTM)
40450 Shah Alam
Selangor, MALAYSIA
E-mail: 2021672794@student.uitm.edu.my, adibah253@uitm.edu.my*

College of Computing, Informatics and Mathematics
University Teknologi Mara (UiTM)
Cawangan Negeri Sembilan
Negeri Sembilan, MALAYSIA
E-mail: zati@uitm.edu.my

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*Corresponding author